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Review of Documents for Operable Unit 2, Site ST012, at the Former Williams Air Force Base, Mesa, AZ

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INTRODUCTION

CSS-Dynamac was tasked by the U.S. Environmental Protection Agency (USEPA) with providing comments related to a proposed enhanced bioremediation (EBR) effort for Operable Unit (OU) 2 Site ST012 (**Site**), at the Former Williams Air Force Base (FWAFB), Mesa, AZ (USEPA Region 9). The Air Force Civil Engineer Center (AFCEC) and their consultants Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler) are directing and conducting Site remediation.

The site-related documents used for site information include:

> Addendum #2 Remedial Design and Remedial Action Work Plan – Site ST012. (**Work Plan**). November 30, 2015.
> *Draft_ST012_RD-RAWP_Addendum2_Section1.pdf*
>
> Site ST012 Update. BRAC Cleanup Team Call. (**17 December 2015 Update**). December 17, 2015. *December 2015 BCT Slides_ST012_.pdf*
>
> Appendix E Enhanced Bioremediation and SEE Containment Modeling Report. (**EBR Modeling Report**). May 2014. *Final_ST012_RD-RAWP_052014 Appendix E.pdf.*
>
> Draft 1 Enhanced Bioremediation Field Test Report. (**EBR Field Test Report**) November 30, 2015. *Draft_ST012_RD-RAWP_Addendum2_Section2a.pdf*

The Site is at the former Liquid Fuels Storage Area of FWAFB, where fuel storage and distribution facilities were located until decommissioning in 1991. Contamination of soil and groundwater occurred when jet petroleum grade 4 (JP-4) and aviation gasoline (AVGAS) was released. Benzene, toluene, ethylbenzene, total xylenes, and naphthalene (BTEX+N), are indicated in the Work Plan to be the contaminants of primary concern (COPC; COC) that require treatment to achieve remediation goals.

Hydrogeological characteristics of the Site include the Upper Water Bearing Zone (UWBZ), the Cobble Zone (CZ), the Low Permeability Zone (LPZ), and the Lower Saturated Zone (LSZ).

As part of remedial activities, steam enhanced extraction (SEE) is being used for the removal of light non-aqueous phase liquid (LNAPL) at specified thermal treatment zones (TTZs). EBR is planned to address BTEX+N in groundwater and LNAPL remaining in the TTZs after SEE, and also outside of the TTZs. The EBR effort involves the injection of sulfate as a terminal electron acceptor (TEA) to enhance the anaerobic biodegradation of the COPCs. The EBR Field Test Report reports the results of a field pilot test of EBR (EBR Pilot Test) at the Site. The Work Plan includes a discussion of proposed plans for implementation of full-scale EBR.

Once EBR reduces benzene concentrations, monitored natural attenuation (MNA) is proposed to be used to achieve the final cleanup goals. The 17 December 2015 Update indicates that:

> "*100 to 500 μg/L [benzene concentration, in micrograms per liter] was set as the goal for SEE in the interior as the concentration range where natural attenuation can complete degradation within the remedy timeframe…*" (17 December 2015 Update, Slide 30)

The Work Plan indicates that:

> "*EBR will be implemented to achieve conditions (residual COC/COPC groundwater concentrations) at ST012 such that contaminants will degrade by natural attenuation to achieve the cleanup levels within the projected remedial timeframe (i.e., about 20 years) after completion of EBR.*" (Work Plan, Lines 1104-1107)

The proposed remedial effort is that after SEE has ceased (which occurred in spring 2016), EBR will be used to bring COPC groundwater concentrations down to a range where MNA will suffice to further reduce COPC concentrations to final required levels, all within a twenty year timeframe. The twenty year timeframe started at the signing of the Site record of decision amendment 2 (RODA 2) which occurred in 2013.

SUMMARY AND CONCLUSIONS

The results of the EBR Pilot Test are equivocal, difficult to interpret for practical use, and result in high uncertainty when used to model and plan full-scale EBR, and MNA.

The proposed approach to full-scale EBR, as described in the Work Plan, is based on the results of the EBR Pilot Test, literature data, and predictive modeling; the estimates of EBR and MNA effectiveness and timeframes are subject to high uncertainty.

The uncertainty involved in the above items, and all further modeling and monitoring, should be quantified and presented clearly according to USEPA data quality and uncertainty analysis guidance for statistical approaches and modeling (USEPA 2009).

Monitoring of EBR, and the following MNA, should include complete delineation (on and off-Site) of contaminant sources, and the dissolved contaminant plume(s).

Significant potential difficulties with implementation and effectiveness of the proposed EBR+MNA remedy indicate that success of this remedial plan is highly uncertain.

Within at the most two or three years after implementation of EBR, monitoring and operational data should be carefully evaluated to determine if the data show that the EBR+MNA approach appears likely to be able to meet Site goals within the remaining portion of the fixed remedial timeframe. If not, final design and implementation of the contingency remedies should begin immediately.

GENERAL COMMENTS

The goal of the proposed remedial approaches (EBR+MNA after SEE) is to bring COPC groundwater concentrations down to meet required levels, within a fixed timeframe as required by RODA 2. Amec Foster Wheeler has conducted Site characterization and monitoring activities, various tests (including the EBR Pilot Test), and modeling exercises to develop assessments of the potential for EBR+MNA (after cessation of SEE) to effectively meet the required COPC groundwater concentrations in the required timeframe.

As discussed in earlier reviews, conference calls, and meetings (and below in this present review), SEE, EBR (sulfate reduction based bioremediation) and MNA do have some potential for being useful for reducing COPC groundwater concentrations at the Site.

However, there are numerous potential difficulties that may adversely affect implementation of the EBR and MNA remedial approaches, including, for example, problems with items such as:

- remaining source materials (i.e., LNAPL) that are not amendable to EBR or MNA,
- COPCs (likely including LNAPL, in addition to dissolved COPCs) outside the area contemplated for treatment,
- difficulty in effective distribution of reagents,
- COPCs remaining in low-permeability zones that are little affected by EBR or MNA,
- well fouling issues,
- generation of high levels of sulfide (potentially affecting needed microbial activities, possibly causing vapor intrusion issues, and perhaps reducing aquifer permeability in some locations due to iron sulfide precipitation), and
- variable rates of COPC degradation (i.e., rates that vary in different parts of the Site, and overall rates that vary significantly lower than those rates used in modeling EBR+MNA effectiveness and timeframes).

Some of these issues can probably be dealt with by particular operational approaches (e.g., a rigorous schedule of well rehabilitation to alleviate well fouling issues, added injection and extraction wells to enhance distribution of reagents, etc.).

However, some of the issues (in particular, remaining source materials, COPCs in low-permeability zones or outside the area contemplated for treatment, and lower than anticipated rates of COPC degradation) may be difficult or impossible to effectively deal with without significantly changing the scope of the remedy. Such changes might include, for example, remobilizing SEE to deal with remaining LNAPL source materials or source materials in low permeability zones; extending EBR outside of the currently-proposed treatment area; or even by changing the proposed remedy altogether (e.g., choosing another remedial approach that is more effective/faster than EBR+MNA).

In any case, it appears that there is good reason to be uncertain that EBR+MNA will be able to achieve remedial goals within the fixed timeframe, even within the TTZ. Therefore it is recommended that within at the most two or three years after implementation of EBR, monitoring and operational data be carefully evaluated to determine if the data (primarily the COPC attenuation data; secondary data such as sulfate utilization are of much less importance for assessment of remedy effectiveness) show that the EBR+MNA approach appears likely to be able to meet Site goals within the remaining portion of the fixed remedial timeframe. If not, final design and implementation of the contingency remedies should begin immediately (it is assumed that potential contingency remedies would have already been screened and evaluated during the two or three years of EBR implementation).

SPECIFIC COMMENTS

EBR Pilot Test Comments

The EBR Field Test Report describes the design, implementation, and results of a field pilot test of EBR (i.e., the EBR Pilot Test) in two wells (ST012-W11 and ST012-W30) at the Site, using a push-pull approach (i.e., injecting a given volume of groundwater amended with high concentrations of sulfate, and after a shut-in period, extracting and analyzing the groundwater, in order to ascertain sulfate utilization). Also, during the shut-in period, low-flow sampling was used to take samples of the groundwater in the wells. A bromide tracer was used to enable estimation of hydrologic factors such as dispersion and dilution.

Note that while estimates of electron acceptor utilization (i.e., sulfate utilization, in this case) are useful, in that they provide an index of the importance of that electron acceptor in biogeochemical processes at the Site, and rates/total mass of electron acceptor used (which are useful design elements), such utilization estimates are not clearly and directly related to efficacy of using that electron acceptor to remediate the COPC. That is, because there are many electron donors present other than the COPCs BTEX+N (the COPCs represent about 10% of the JP-4 and AVGAS contaminants), a given mass of sulfate utilized does not mean that a corresponding stoichiometric amount of COPC was degraded. The actual degradation (or, at least, attenuation/disappearance) of COPCs is the overriding factor of importance, not sulfate utilization.

It is difficult to readily interpret the result of the EBR Pilot Test due to problems encountered during the execution of the EBR Pilot Test. Problems include:

EBR Field Test Report, Lines 327-330

"*Initial results from Test America for the pull-phase of ST012-W11 were used to calculate the total amount of sulfate that was extracted from the groundwater. The results of this calculation indicated that more sulfate was extracted from the groundwater than was introduced during the push-phase of the field test.*"

Therefore the approach of comparing total sulfate injected to total sulfate extracted was not usable for estimating sulfate utilization. Instead, groundwater samples taken during the shut-in phase were used for sulfate utilization estimation. Note, however, that only part of the sulfate concentration data taken during shut-in were deemed useful for estimating sulfate utilization because the normalized sulfate concentrations of the samples were higher than the normalized bromide tracer concentrations for most of the test period.

Note also that the calculated (i.e., calculated according to how much sulfate or bromide was added to the injection solution) values for sulfate and bromide were significantly different from the measured values (i.e., lab-measured on samples taken from the injection solution) of sulfate and bromide in the injection solution. It is not clear why the lab-measured sulfate and bromide concentrations in groundwater samples were normalized using the calculated values in the injection solution, not the lab-measured values. In some cases, this approach made a significant difference in the normalized values. It would be useful to explain why this approach was taken. Also, it would be useful to explain why the calculated values were in some cases so different from the lab-measured values, and how this difference might affect evaluation and interpretation of the results of the EBR Pilot Test, and reliability of lab-measured values.

EBR Field Test Report, Lines 372-378

"*Due to the slow extraction rates achievable from ST012-W30, only 1,000 gallons of water was removed during the extraction phase compared to the 10,000 gallons targeted in the EBR Field Test Plan. This may be due to fouling of the well over time. Well fouling limits evaluation of hydraulic conductivity for the well. Extraction of a smaller volume of water than planned results in only partial extraction of the injected fluids. This limits evaluation of degradation kinetics; however, data from the shut-in phase is available for calculation of kinetic parameters.*"

Here again the approach of comparing sulfate injected to sulfate extracted was not usable for calculating sulfate utilization, so samples of groundwater taken during shut-in were used.

Note also that well fouling was a problem; it is very likely that well fouling will be a significant problem during full-scale implementation of EBR (i.e., during the injection of tons of sulfate, and extraction of groundwater for control of circulation of the sulfate and control of plume behavior).

<u>EBR Field Test Report, Lines 383-392</u>

> "*Analytical concentration data for ST012-W11 presented in Table 2-1 show no significant change between the baseline and the post-shut-in period for most of the analytes evaluated. However, there is a decrease in total TPH and total VOC concentrations observed between these monitoring periods and the post-extraction sampling round. Additionally, sulfate, calcium and chloride concentrations for the post-shut-in period increased as well. These conditions were not expected and are interpreted to be a result of cleaner/background groundwater within part of the screened interval being drawn into the well rather than pulling only injected water back into the well. Historical groundwater monitoring upgradient of site contamination has shown background sulfate concentrations generally range from 250 to 300 mg/l (BEM, 1998) which is similar to the concentrations observed in ST012-W11 during the pull phase.*"

Therefore the interpretation of sulfate utilization and changes in contaminants in the EBR Pilot Test are problematic at best.

<u>EBR Field Test Report, Lines 394-396</u>

> "*Results for ST012-W30 presented in Table 2-2 indicate an increase in concentration for total TPH and total VOCs in both the post-shut-in sample and post-extraction sample in comparison with the baseline sample results.*"

So it is not clear what useful effect, if any, sulfate injection might have on contaminant concentrations.

<u>EBR Field Test Report, Lines 427-431</u>

> *"Water elevations from transducer data collected throughout the field test were evaluated for estimation of hydraulic parameters. However, groundwater elevation data from the transducers generally showed rapid and abrupt changes during the pull phases which was likely related to fouling of the well screens; this limited analysis of pull phase data for estimation of hydraulic conductivity."*

Again, fouling is likely to be a significant problem at full-scale. Also, the EBR Pilot Test was not able to provide useful estimates of hydraulic conductivity, as might have been expected. Hydraulic conductivity is an important parameter for designing models of groundwater flow, and reagent/contaminant fate and transport. The proposed remedial scheme for the Site depends largely on models for justifying the remedial approaches to be taken, and calculating remedial timeframes.

<u>EBR Field Test Report, Lines 484-487</u>

> "*The normalized sulfate concentration is higher than the normalized bromide concentration for the majority of the shut-in period* [in well ST012-W11]*; however, after the initial 24 July 2014 sample, sulfate decreased faster than bromide and the data after this date are useful for evaluating the sulfate utilization rate.*"

The data chosen for evaluating the sulfate utilization rate for well ST012-W11 were from only about 20 days at the end of the test period (the test period of about 48 days was from sulfate injection on July 21, 2014 to the end of extraction on September 7, 2014). So only a small part of the test period contributed data to the sulfate utilization analysis.

Given, then, the secondary importance of measures of sulfate utilization (i.e., not a direct measure of COPC degradation), the various problems mentioned above in respect to measuring the sulfate utilization, and problems with well fouling and hydraulic measurements, and the relatively small amount of usable data generated), it is difficult to derive strong and useful conclusions from the results of the EBR Pilot Test. Also, the EBR Pilot Test involved only a very small portion of a large and complex site, over a short time period (i.e., as opposed to a twenty-year remedial timeframe) so extrapolation of the EBR Pilot Test results to the rest of the Site, over a long timeframe, increases uncertainty. In sum, the EBR Pilot Test appears to provide data of limited utility for design on a full-scale EBR effort, and particularly for evaluating and predicting remediation effectiveness in achieving the desired COPC concentrations, degradation rates, and remedial timeframes.

It is concluded, therefore, that the results of the EBR Pilot Test should be used with caution when assessing the potential for EBR remediation at the Site. Modeling efforts based on parameters derived from the EBR Pilot Test should be considered to be highly uncertain as far as predicting contaminant attenuation rates (both for EBR and MNA), and for predicting remedial timeframes. Given the limited utility of the EBR Pilot Test data, and the fact that the efficacy and timeframes of both the EBR full-scale effort and the proposed MNA following are based on modeling using the EBR Pilot Test data and literature (i.e., non-site-specific) data, (i.e., not on a robust collection of long-term site-wide site-specific monitoring data showing effectiveness and rates of sulfate reduction-based biodegradation of the COPCs), it is not clear that the proposed EBR/MNA remedial effort is appropriate.

Work Plan Comments

Work Plan, Lines 259-268

> "*The pre-SEE LNAPL Extent Interpretation Update assumes only residual LNAPL at ST012. Between the start of SEE operations and 13 November 2015, greater than 3,500 gallons of mobile LNAPL were removed by bailing and/or pumping from three perimeter monitoring wells (further discussed in Section 2.2.3). The presence of mobile LNAPL during the PDI and the volumes removed during SEE operations indicate that there is mobile LNAPL at ST012; however, it is expected that mobile LNAPL at ST012 is limited in extent compare to residual LNAPL and will be removed via mechanical extraction from wells during both the remainder of SEE operations and EBR system implementation. Because of this, the pre-SEE extent based on residual LNAPL described in this section is used to develop the EBR system design, including required TEA mass calculations.*"

"*Assumes only residual LNAPL*", "*it is expected that mobile LNAPL at ST012 is limited in extent*". While the Site documents present various arguments for these assumptions, it is not clear that there are robust data providing a strong scientific basis for these assumptions and expectations. Therefore, basing the EBR system design on them is problematic.

It may be worth noting that if it is feasible to remove much mobile LNAPL by mechanical extraction ("*mobile LNAPL at ST012 ... will be removed via mechanical extraction from wells*") from wells, it's not clear why this has not been done already. There was some discussion of this possible mechanical extraction effort in the *APPENDIX I Response to EPA Review Comments* portion of the Work Plan, but the discussion did little to clarify the value of such an effort.

Work Plan, Lines 331-334

> "*Monthly perimeter monitoring well groundwater sampling is conducted at the site to monitor COC concentrations throughout SEE operations (well locations shown in Figure 2-4). Table 2-3 presents the most recent round of perimeter groundwater monitoring data, as well as the minimum and maximum concentrations measured at each well since startup.*"

> "*Table 2-3 BTEX+N Groundwater Concentrations During SEE Operations*"

Perimeter Monitoring Wells ST012-W11, ST012-W30, ST012-W34, ST012-W36, ST012-W37, and ST012-W38 all show high contaminant concentrations (i.e., one or more of the BTEX+N contaminants). Of these, ST012-W11, ST012-W30, and ST012-W37 have measurable LNAPL in the well (Work Plan, Lines 368-371). Given that these wells are perimeter wells, and there is little monitoring outside the perimeter, it is clear that the plume(s) have not been completely delineated. This lack of plume delineation is problematic not only for EBR, but also for MNA, because EPA policy is that in order for MNA to be chosen as part of a site remedy, the plume has to be completely delineated.

> "*Site characterization should include collecting data to define (in three spatial dimensions over time) the nature and distribution of contaminants of concern and contaminant sources...*" (USEPA 1999, p14)

In addition, USEPA policy for MNA is that contaminant sources must be controlled.

> "*Furthermore, largely due to the uncertainty associated with the potential effectiveness of MNA to meet remediation objectives that are protective of human health and the environment, EPA expects that source control and long-term performance monitoring will be fundamental components of any MNA remedy.*" (USEPA 1999, p3)

While significant amounts of source material have been removed (e.g., during SEE) it is clear that significant amounts of source material remain (i.e., NAPL in wells, and high COPC concentrations remaining in some locations both within the main part of the Site and outside in the largely-uncharacterized areas around the Site). Therefore MNA is not applicable for the Site due to the lack of contaminant source control.

Note also that the EBR Field Test Report indicates that:

> "*As part of the ST012 Remedial Design and Remedial Action Work Plan (RD/RAWP) (AMEC, 2014a) for implementing the OU-2 RODA 2, the selected remedial action includes an initial period of SEE for mass removal of dissolved contaminants and light non-aqueous phased liquid (LNAPL) within established thermal treatment zones (TTZs),*

> ***followed by EBR to address LNAPL** outside of the TTZs as well as dissolved phase contaminants within and outside the TTZs.*" (EBR Field Test Report, Lines 148-152; emphasis added)

EBR is not a source (e.g., LNAPL) remedy. EBR might have some efficacy for reducing mass flux of contaminants from source materials into groundwater, but the timeframe for actual removal of a significant mass of source material (e.g., removing the many thousands of pounds of source material estimated to remain after SEE, by dissolution into groundwater and then EBR degradation of the dissolved contaminants) would likely be far longer than the less-than twenty years remaining in the RODA-specified remedial timeframe. The problem with proposing EBR to address LNAPL source materials has been mentioned in previous conference calls, but the *APPENDIX I Response to EPA Review Comments* portion of the Work Plan still indicates that "*SEE is the primary removal mechanism for LNAPL but the RD/RAWP identified that EBR would also address LNAPL*".

Work Plan, Lines 413-427

> "*COC mass remaining at ST012 was estimated using assumed removal percentages for the TTZ and two zones outside of the TTZ. Based on previous SEE experience, treatment within the TTZ was estimated to remove 90% of initial LNAPL mass. Based on observed temperature increases outside of the TTZ (as described in Section 2.2), a zone of treatment (Thermal Influence Zone [TIZ]) was estimated 10 meters outside of the TTZ. Treatment in this zone was not expected to be as effective because temperatures in this zone have been elevated but have not reached steam temperatures as within the TTZ, so removal was estimated at 60%. A third treatment zone (Radius of Influence [ROI] Zone) was estimated 10 meters outside of the TIZ. Treatment was not targeted or expected in the ROI Zone; however, it has been subject to elevated temperatures and influence from the outer extraction wells. Removal in the ROI Zone is estimated at 30%. The LPZ has not been targeted for SEE treatment because of the difficulties related to injecting steam and extracting liquids and vapor from low permeability soils. However, the LPZ has been influenced by thermal conduction from both the UWBZ and the LSZ, so some treatment is to be expected as LNAPL is driven from the liquid to vapor phase. Because of this, treatment of the temperature-affected LPZ adjacent to the TTZ in the UWBZ and LSZ is estimated at 30%.*"

Even based on these (likely optimistic) estimates, significant contaminant mass remains (many thousands of pounds). As mentioned above, EBR is not a source remedy (e.g., for removal of LNAPL), so the remaining source material will continue to supply contaminants to groundwater for many years (likely well beyond a twenty-year timeframe). In addition, the estimate of only 30% of contaminant mass removal from the LPZ indicates that this zone will continue to supply (e.g., through back diffusion from these low permeability materials) significant quantities of contaminants to groundwater, and over a much longer time period than the more permeable materials.

Work Plan, Lines 619-624

> *"The primary advantages of oxygen as a TEA over sulfate are its faster degradation kinetics and a more extensive track record than sulfate for enhancement of petroleum hydrocarbon degradation. However, these advantages were offset by several other factors that led to the selection of sulfate as the primary TEA at ST012 including:*
>
> - *sulfate was demonstrated in the RD/RAWP to be capable of achieving goals in the target timeframes..."*

The selection of sulfate over oxygen is reasonable, but it is not at all clear that sulfate EBR is "*capable of achieving goals in the target timeframes...*". The "demonstration" appears to be based on modeling efforts based on limited Site data, numerous assumptions, and the EBR Pilot Test, not (as mentioned in an earlier part of this review) on a robust collection of long-term site-wide site-specific monitoring data showing effectiveness and rates of sulfate reduction-based biodegradation of the COPCs. The EBR Pilot Test, as discussed above, added relatively little useful data to back up the modeling assumptions and estimates. Therefore sulfate EBR has not been practically demonstrated to be capable of achieving goals in the target timeframes. Perhaps sulfate EBR has been demonstrated (under an optimistic view of sulfate distribution, COPC degradation rates, mass and distribution of remaining COPC source material/dissolved COPCs on and off-Site, etc.) to be theoretically capable (i.e., under some modeling scenarios) of achieving goals in the target timeframes. However, the practical value of such a theoretical demonstration remains to be seen.

EBR Monitoring Comments

The EBR plan includes using sulfate injection wells, and groundwater extraction wells, to enhance and control distribution of reagents throughout the contaminated zone. These injection and extraction wells are proposed to be used for monitoring treatment efficacy and rates also.

As was discussed in earlier USEPA comments and conference calls, injection wells are not suited for monitoring sulfate reduction and contaminant degradation, generally, though the monitoring data from such wells is useful. Extraction wells may be useful for monitoring sulfate reduction and contaminant degradation. However, there must be additional monitoring wells used for monitoring sulfate reduction and contaminant degradation (i.e., treatment efficacy and rates). These problems were discussed and addressed to a degree in the *APPENDIX I Response* *to EPA Review Comments* portion of the Work Plan, but are enlarged upon in this review to emphasize the necessity differentiation of the data derived from the different types of wells.

Injection wells generally work effectively to produce a treated zone immediately around the well, and any samples drawn from such well either include the treated water from immediately around the well (e.g., using low flow sampling) or at least draw formation water through a strongly active treatment zone immediately around the well, so such samples are not particularly representative of treatment in the larger aquifer volume.

Extraction wells are more suitable for monitoring treatment efficacy and rates, but nevertheless data from such wells can be problematic because the design and purpose of such wells is to (eventually) draw in water from the injection wells (i.e., water from pathways where distribution of the injected reagents has been successful). That is, the extraction wells are supposed to help move water and reagents from the injection wells through the Site to the extraction wells, thereby helping enhance and control reagent distribution. So, as by design the extraction wells tend to capture water from pathways where reagent distribution (and presumably, treatment) has been successful, the data from such wells may be biased toward showing more effective treatment than is actually the case in the larger aquifer.

Also, the geochemistry around the extraction wells can be changed due to the continuing withdrawal of relatively large volumes of water (as compared to the small volumes of sample taken from ordinary monitoring wells), possibly biasing the monitoring results from such wells.

Therefore, it is important to:

- Evaluate data from the three types of wells (injection, extraction, and monitoring-only wells) separately, to avoid comingling of data with different biases.

- Provide sufficient monitoring-only wells so that treatment efficacy and rates, geochemistry, etc., can be properly evaluated throughout the Site and outside the Site.

Data Presentation Comments

Data for each monitoring well should be presented separately in tables and figures, to show changes in contaminants and geochemistry. For purposes of overall screening of results, data for injection wells, extraction wells, and monitoring wells could be grouped (i.e., the group of injection wells, the group of extraction wells, and whatever groups of monitoring wells [e.g., perimeter, TTZ, etc.] might be appropriate) and presented separately from the individual wells.

All such tables and figures providing the monitoring data, and associated discussions, should include materials showing how the data collection, analysis and evaluation, and all modeling and statistical approaches meet USEPA data quality objectives. Uncertainty analyses, including sensitivity analyses, confidence limits on predicted values, etc. should be included. The uncertainty analyses should clearly indicate the variability of Site data, and how that variability influences assessment (i.e., understanding of current Site conditions, including hydrogeology, contamination, geochemistry, and microbiology) and predictions of contamination nature (e.g., changes in the BTEX+N mix), contaminant extent (3D location, including off Site areas) and contaminant degree (concentration/mass, including attenuation rates), future changes in Site conditions (hydrology, geochemistry, microbiology, etc.), and predicted timeframes for meeting remedial goals (USEPA 2009). Given the heterogeneous nature of the Site hydrogeology and contaminant nature and distribution, and the problematic nature of the EBR Pilot Study results, it is important to clearly convey the high uncertainty associated with predictions of remedy (e.g., EBR and MNA) success and timeframes.

REFERENCES

USEPA. 1999. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. OSWER Directive 9200.4-17P. April 21, 1999. Office of Solid Waste and Emergency Response.

USEPA. 2009. EPA Quality System. http://www.epa.gov/quality/qa_docs.html